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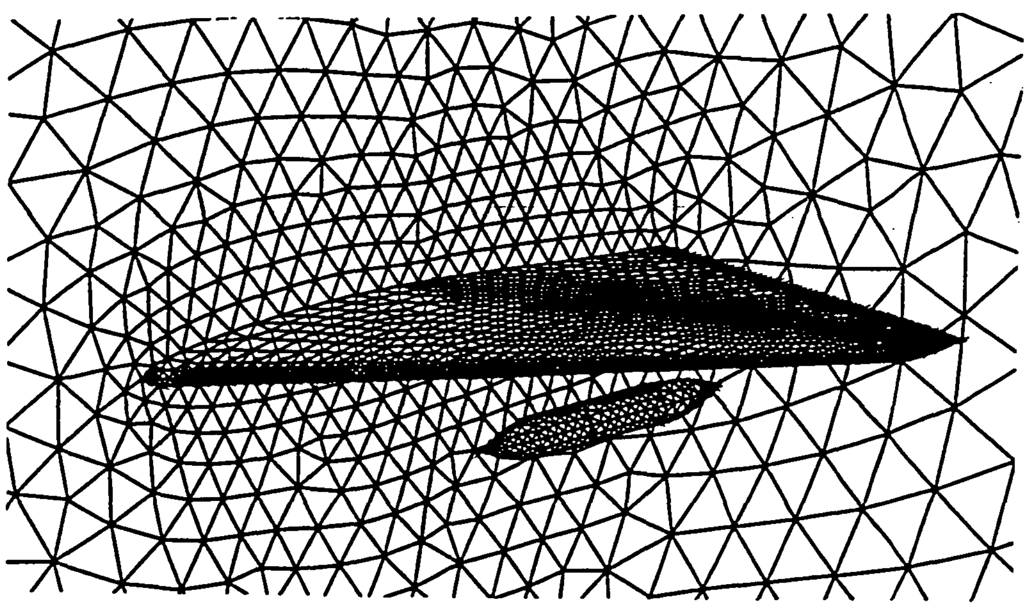

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3-D Unstructured Method for Flows past Bodies in 6-DOF Relative Motion

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A three dimensional, unstructured-mesh methodology was developed to simulate unsteady flows past bodies in relative motion, where the trajectory was determined from the instantaneous aerodynamics. The method coupled the equations of fluid flow and those of rigid-body dynamics, and captured the time-dependent interference between stationary and moving boundaries. The unsteady, compressible Euler equations were solved on dynamic, unstructured meshes by an explicit, finite-volume, upwind method. The grid adaptation was performed within a window placed around the moving body. The Euler equations of dynamics were solved by a Runge-Kutta integration scheme. The flow solver and the adaptation scheme were validated by simulating the transonic, unsteady flow around a wing undergoing a forced, periodic pitching motion, then, comparing the results with the experimental data. To validate the trajectory code, the six-degrees-of-freedom motion of a store separating from a wing was computed using the experimentally determined force and moment fields, then comparing with an independently generated trajectory. Finally, the overall methodology was demonstrated by simulating the unsteady flowfield and the trajectory of a store dropped from a wing. The methodology, its computational cost notwithstanding, has proven to be accurate, automated, easy for dynamic gridding, and relatively efficient for the required man-hours.

INTRODUCTION

Computational fluid dynamics has reasonably matured for steady flows. However, there is a strong need for advancements to compute unsteady flows and, in turn, the flows involving moving boundaries. In simulating a flowfield involving a multicomponent configuration, with one or more components engaged in a relative motion, there are at least four levels of assumptions that can be made for the incident-flow and solid-surface interaction. From the least to the most accurate, they are: 1) All the moving components are assumed to be instantaneously *frozen*, and at each instant, a steady-state computation is performed. 2) *All* the moving components are assumed to be engaged in the *same* rigid-body motion, and the complete computational grid is assigned this motion during the unsteady flow analyses (e.g. Ref. 1). 3) Each moving component is assigned its own rigid-body motion, but it is assumed to be known, so it can be *prescribed* as input to the unsteady flow computations (e.g. Refs. 2-6). 4) Beyond and above level 3, the trajectory is determined from the instantaneous flowfield, i.e. *aerodynamically determined.*

For certain class of relative-moving-body problems, levels 1-3 may be unacceptably compromising. Currently, there appear to exist two different approaches at level 4: dynamic domain decomposition (e.g. Ref. 7) and dynamic unstructured methods (e.g. Refs. 8 and 9). The objective of the present paper is to report the latter method's extension to three-dimensional flows with six degrees-of-freedom (DOF) boundary motions (Fig. 1).

SYNOPSIS OF METHODOLOGY

The three-dimensional (3-D), time-dependent Euler equations, expressed in the integral form for a bounded domain Ω with a boundary ∂S,

$$\frac{\partial}{\partial t}\iiint_{\Omega} \bar{Q}\, d\Omega + \iint_{\partial S} \bar{E}(\bar{Q})\cdot\hat{\eta}\, dS = 0, \qquad (1)$$

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